Transportation Synthesis Report

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Recent Developments in Concrete-on-Concrete Bridge Deck Overlays

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research. Internet hyperlinks in TSRs are active at the time of publication, but changes on the host server can make them obsolete.

REQUEST FOR REPORT

The Bureau of Highway Construction asked the Research, Development and Technology Transfer Program to conduct a brief search for domestic and international research and practices related to the placement of concrete overlays over concrete bridge decks, including replacement of milled-off asphalt and concrete layers.

SUMMARY

A search of Internet and international transportation research databases, augmented by dialogue with Transportation Research Board staff, shows Virginia and the Virginia Transportation Research Council to offer the most thorough study of research and practice in the use of concrete overlays on concrete bridge decks over the last decade. Concrete overlays of concrete bridge decks in Europe and other areas of the world were not widely reported on international transportation Web sites.

The rub in overlay mix design, the central focus of the research we present, is achieving the delicate balance between chloride-impermeable concrete of low, but workable, water content, and a crack-resistant concrete typical of higher water content that will avoid providing chloride easy passage through fissures to important bridge structural members. Bonding remains the critical factor, according to the VTRC, in durability for concrete overlays of bridge decks. However, issues of interest in the research throughout this country also include permeability, recycled and alternative admixture materials, the usefulness of milling deck surfaces prior to overlay, polymer- and latex-modified cement mixtures, and more.

Below we summarize research from Virginia, and follow with work from other states on concrete overlays of concrete bridge decks. We cite an exhaustive synthesis report from NCHRP about concrete bridge deck performance, a study posted online in November 2004 that focused on mix design and construction but holds obvious implications for rehabilitation efforts, particularly in its suggestions regarding byproduct use, admixtures, and water-cementitious levels. We also cite some newer developments in concrete overlays that may impact practices in coming years.

VIRGINIA

For decades the Virginia Transportation Research Council has been studying concrete overlays of concrete decks, focusing on bonding issues as critical to durability, the use of different materials, even the impact of various machines used in concrete removal. The VTRC's associate director, Michael Sprinkel, is VDOT's resident expert, and author or co-author of each of the following research documents.

***Performance Specifications for High Performance Concrete Overlays on Bridges*, Aug. 2004.** This study by Sprinkel focuses on performance specifications for hydraulic cement concrete overlays, paying attention to bond, the most important factor in overlay durability; permeability; air content; and more. See http://www.virginiadot.org/vtrc/main/online_reports/pdf/05-r2.pdf.

***Evaluation of Corrosion Inhibitors for Concrete Bridge Deck Patches and Overlays*, June, 2003.** Sprinkel's report distills results from a five-year pooled fund study that concluded in 2001 (and in which WisDOT participated) to conclude that corrosion inhibiting admixtures and topical applications on chloride-contaminated concrete surfaces fail to produce any significant benefit to repair and overlay efforts. http://www.virginiadot.org/vtrc/main/online_reports/pdf/03-r14.pdf.

"Shrinkage of Latex-Modified and Microsilica Concrete Overlays," P. Buchanan, D. Mokarem, R. Weyers, M. Sprinkel, *Transportation Research Record 1834, Concrete 2003*; 33-39. Studying shrinkage in the field and lab of VDOT mixes for bridge overlays, researchers developed a shrinkage performance-based specification. Unrestrained mix samples of both types performed roughly the same, but restrained microsilica concrete cracked sooner and more frequently than latex-modified. Bridge deck crack and delamination surveys pointed to traffic, construction quality, and conditions as more significant factors than overlay material. See abstract at http://trisonline.bts.gov/detail.cfm?ANNUMBER=00964827&STARTROW=1&CFID=1227467&CFTOKEN=31975815. Available at WisDOT Library, 8th Floor, Hill Farms.

***Evaluation of High Performance Concrete Overlays Placed on Bridges and Pavements in Virginia,* Aug. 2001.** In this brief covering several studies, high performance concrete overlays of hydraulic cement concrete were recommended to stand two to four inches thick; effective mixes could be made with admixtures of silica fume, fly ash, slag, latex, and more; and milling of old concrete proved damaging. http://www.virginiadot.org/vtrc/briefs/01-r1rb/High_Performance_Concrete.htm.

***Evaluation of Latex-Modified and Silica Fume Concrete Overlays Placed on Six Bridges in Virginia*, Aug. 2001.** Sprinkel found these overlays viable, showing good skid resistance and low permeability in the first five years of service. Bonding was inhibited by milling of old surfaces. http://www.virginiadot.org/vtrc/main/online_reports/pdf/Microsoft%20Word%20-%20VTRC%2001-R3%20_Sprinkel_.pdf.

***Effect of Concrete Removal Equipment and Methods on the Condition of Deck Concrete Left in Place*, Aug. 2000.** Of peripheral value for this report, this study shows that hoe rams or crushers outperform hammers in concrete removal both in terms of cost and impact on the existing structure. For 2001 VTRC brief, http://www.virginiadot.org/vtrc/briefs/01-tar1/index.htm; for study, http://www.virginiadot.org/vtrc/main/online_reports/pdf/Microsoft%20Word%20-%20VTRC%2001-TAR1%20_Sprinkel_1.pdf.

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SOUTH DAKOTA

The following study in South Dakota presented the benefits of non-metallic fiber-reinforced concrete for bridge deck overlays.

***The Determination of the Permeability, Density, and Bond Strength of Non-metallic Fiber Reinforced Concrete on Bridge Deck Overlay Applications*, V. Ramakrishnan and Kumar Santhosh (July, 2000).** Researchers compared use of low-slump dense concrete, a nearly impermeable barrier between concrete decks (and in older bridges, black steel decks) and overlay, with the use of a non-metallic fiber-reinforced concrete. Findings include:

- NMFRC should be used for concrete overlays of badly deteriorated decks;
- NMFRC minimizes propagation of cracks and spalling from the old, overlaid concrete;
- Bond strength between layers was stronger than the tensile strength of the old concrete;
- Bond strength of NMFRC to old concrete was adequate;
- Bond failures occurred only due to tensile strength problems in the old concrete;
- In lab and field, NMFRC chloride permeability and density were similar to LSDC.

http://www.state.sd.us/Applications/HR19ResearchProjects/Projects/sd1998_18_final_report.pdf.

TENNESSEE

Various overlays, including two of concrete, were considered in this 2004 TRB Annual Meeting paper on the use of overlays as a maintenance tactic for extending worn deck life.

***Overlay Types Used as Preventive Maintenance on Tennessee Bridge Decks*; Marcus Knight, G. Scott Wilson, Wayne Seger, and Sankaran Mahadevan, TRB 2004 Annual Meeting.** Asphalt, reinforced Portland cement concrete, polymer-modified concrete, and thin-bonded overlays were all compared for cost, service-life, performance, and the study includes details on surface preparation. PMC emerges as an attractive concrete option for its lower cost and similar durability to RPCC. See TRB 2004 Annual Meeting Compendium of Papers CD-ROM, WisDOT Library, 8th Floor, Hill Farms.

NCHRP

In a study published late last year, researchers review and summarize research and practice in concrete bridge deck building and mix design from around the country. Though removal and replacement of decks is not the direct focus of this study, rehabilitative choices can clearly benefit from the study.

NCHRP Synthesis 333: Concrete Bridge Deck Performance, 2004. This detailed report considers deck overlays as a protective system, and balances the tension between low-water cementitious mixes that resist chloride penetration and higher-water mixes that suffer less of the cracking that provides chloride easy passage to main structural components. See http://trb.org/publications/nchrp/nchrp_syn_333.pdf. Current practices and research recommendations include:

- Fly ash as up to 35 percent of total cementitious content;
- Silica fume up to 8 percent;
- Ground-granulated blast furnace slag up to 50 percent
- Aggregates with low modulus of elasticity
- Largest aggregate size feasible;
- Water-reducing admixtures.

OTHER AGENCIES

Our search turned up the following papers that bear on the use of concrete bridge deck overlays, though remain somewhat peripheral to the focus of this report.

Nebraska. Carbon powder proves the additive of choice for the rarefied practice of creating conductive concrete overlays for electrically heated bridges.

***An Implementation of Using a Conductive Concrete Overlay for Bridge Deck Deicing at Roca, Nebraska*; Sherif Yehia and Christopher Tuan, TRB 2004 Annual Meeting.** Researchers provide details of a Nebraska heated bridge deck that employed a conductive concrete overlay designed for anti-icing performance. An effective deicing technology, the concrete employs not steel shavings but rather carbon powder and particles for conductivity. See TRB 2004 Annual Meeting Compendium of Papers CD-ROM, WisDOT Library, 8th Floor, Hill Farms.

Pennsylvania and South Korea. The following 2004 TRB Annual Meeting paper finds latex-modified concrete overlays superior to non-modified.

***Durability of Rapid-Setting Latex Modified Concrete Against Freeze-Thaw and Chemicals*; Kyong-Ku Yun, Dong-Ho Kim, and Sung-Yong Choi, TRB 2004 Annual Meeting.** A joint study by South Korean and Pennsylvania researchers found that latex-modified concrete, used in deck overlays since the late 1950s, outperform non-modified concrete in deicing scaling evaluations; both materials perform well in terms of freeze-thaw behavior. See TRB 2004 Annual Meeting Compendium of Papers CD-ROM, WisDOT Library, 8th Floor, Hill Farms.

Chicago. The new bridge on Wacker Drive in the loop of downtown Chicago features a high-performance, latex-modified concrete overlay. The material was selected based on performance testing against 13 other mixes, testing that evaluated shrinkage, chloride permeability, freeze thaw resistance, etc. See this description of the project as it was being built. http://www.cement.org/pdf_files/hpc-19janfeb02.pdf.